Integrating the Usability into the Software Development Process
A Systematic Mapping Study

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Abstract: With the increasing use of interactive applications, there is a need for a development with better quality and a good interaction that facilitates the use for end users, because such applications are increasingly present in daily life. Therefore, it is necessary to include usability, which is one of the important quality attributes, in the development process for obtaining good acceptance rates and, consequently, improving the quality of these applications. In this paper we present a Systematic Mapping Study (SM) that assists categorizing and summarizing technologies that have been used in order to improve usability. The results from our SM show some technologies that can help improving usability in various applications. Also, it identifies gaps that still need to be researched. We found that most technologies have been proposed for the Testing phase (67.28%) and that Web applications are the most evaluated type of application (52.65%). We also identified that few technologies assist designers improving usability in the early stages of the development process (13.50% Analysis phase and 15.95% Design phase). The results from this SM allow observing the state of the art regarding technologies that can be integrated into the development process, aimed at improving the usability of interactive applications.

1 INTRODUCTION

The development of interactive applications has increased considerably. The success of these applications is related to the quality they provide to their end users. Therefore, there is great concern on the part of software companies to produce high quality applications and to ensure a good user experience (Sangiorgi and Barbosa, 2010).

Developing interactive applications meeting quality criteria as well as the users' needs is a complex activity. To minimize this problem, the areas of Human Computer Interaction (HCI) and Software Engineering (SE) have proposed methods and techniques that reflect the different perspectives in the development process (Barbosa and Silva, 2010) and aimed at improving the quality of these interactive applications.

HCI focuses, generally, on understanding the characteristics and needs of the system's users, in order to design a better user–system interaction (Preece et al., 1994). On the other hand, SE has developed systematic approaches to improve quality during development process of interactive applications (Nebe and Paelke, 2009). Therefore, in order to improve the quality of applications, it is necessary to integrate the approaches proposed by the HCI and SE areas. With this integration, there will be a mutual understanding between the two areas, ensuring that problems encountered in the development of the application are handled properly throughout the development process (Juristo et al., 2007). Several researches have been investigating how to integrate the areas of HCI and SE. One of the existing proposals is to incorporate the methods and techniques proposed in HCI, which focus on improving the usability of applications, in the development processes proposed by SE (Fischer, 2012; Nebe and Paelke, 2009; Juristo et al., 2007).

Usability plays a critical role in interactive applications and, it is a key quality factor that should be considered during the development process (Fischer, 2012). According to ISO/IEC 9241-11 (1998) standard usability is defined as "the extent to which a product can be used by specified users to achieve specific goals with effectiveness, efficiency and satisfaction in a specified context of use". Integrating usability in the development process has several benefits such as reduction of documentation and training costs, as well as improving the

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productivity of the practitioners (Carvajal, 2009). Usability is one of the critical success factors of applications (Juristo et al., 2007) and an important criterion for the acceptance of applications by end users (Conte et al., 2010).

We performed a Systematic Mapping Study (SM) in order to identify technologies that integrate usability into the software development process. In the context of this paper, the term technology is used as a generalization of methods, techniques, models, tools, approaches, and other proposals made by the areas of HCI and SE. This SM provided a body of knowledge of technologies that assist in improving usability through various artifacts that are generated during the development process of the applications. This SM also aims at assisting practitioners of the software companies in choosing technologies that will help them design/evaluate the usability within the development process, through the classification carried with each technology.

This paper is organized as follows: Section 2 describes the research method used; Section 3 shows the quantitative results; in Section 4, the qualitative results are presented; Section 5 shows some discussions and finally in Section 6 we present our conclusions.

2 RESEARCH METHOD

A Systematic Mapping Study (SM) is a method of categorizing and summarizing the existing information about a research question in an unbiased manner (Kitchnham and Chartes, 2007). The activities concerning the planning and conducting stages of our SM are described in the next sub-sections and the results are presented in Section 3 and Section 4.

2.1 Research Question

The goal of our study is to examine technologies that aim at improving the usability of applications, from the point of view of the following research question: *“What technologies can improve the usability in the software development process?”*. Since the research question was fairly wide, we defined Sub-Questions to answer specific questions about each technology in Sub-section 2.2.4.

2.2 Search Strategy

Two main digital libraries were used to search for studies: IEEEXplore and Scopus. These libraries were chosen because: (1) have a good operation and scope of the search engines; and (2) Scopus is the largest database indexing abstracts and citations (Kitchenham and Chartes, 2007). To improve the automatic search of the selected digital libraries, we used the PICOC (Kitchenham and Charters (2007):

(P) Population: Software development process;

(I) Intervention: HCI or SE technologies that are used in the software development process;

(C) Comparison: Not applicable, since the goal is not to make a comparison between technologies, but to characterize them;

(O) Outcome: The improvement of the application in terms of usability through the developed artifacts by using the technologies that design/evaluate usability attributes;

(C) Context: Not applicable, since there is no comparison, it is not possible to determine a context.

After that, were searched terms that represented the (P), (I) and (O) and designed a search string. Table 1 shows the search string in which Boolean OR has been used to join alternate terms, while the Boolean AND has been used to join the three parts.

Table 1: Applied search string.

Population	(software development OR software project OR software engineering OR software process)	AND
Intervention	(technique OR method OR methodology OR tool)	AND
Outcome	(usability inspection OR usability evaluation OR usability design OR usability testing)	

2.3 Selection of Papers

In the first step, called 1st filter, two researchers evaluated only the title and the abstract of each paper to according inclusion and exclusion criteria (see Table 2) and selecting papers that would be within the scope of the research question.

In the second stage (or 2nd filter), researchers conducted a thorough reading of the selected papers from the 1st filter. And the papers were included/excluded according to the inclusion and exclusion criteria.

Table 2: Inclusion/Exclusion Criteria.

#	Inclusion Criterion
IC1	Papers describing HCI and SE technologies that are applied to promote the usability in the software development process can be selected;
IC2	Papers presenting tool support that can be employed by designers to improve the usability of the software process can be selected;

Table 2: Inclusion/Exclusion Criteria (cont.).

#	Inclusion Criterion
IC3	Papers that discuss aspects regarding the inclusion of usability in the software process can be selected;
IC4	Papers that have improved usability in one of the phases of the software process in any organization can be selected.
#	**Exclusion Criterion**
EC1	Papers in which the language is different from English and Portuguese cannot be selected;
EC2	Papers that are not available for reading and data collection (papers that are only accessible through paying or are not provided by the search engine) cannot be selected;
EC3	Duplicated papers cannot be selected;
EC4	Publications that do not meet any of the inclusion criteria cannot be selected.

2.4 Strategy for Data Extraction

We extracted the following information from each of the selected papers.

Regarding SQ1 (*Type of Technology*), its goal was to identify the type of technology described in the paper, such as method, technique, template, tool or another procedure adopted in HCI or SE.

Regarding SQ2 (*Origin of the Technology*), its goal was to identify if the identified technologies are new or have been created based on other technologies proposed in the HCI or SE areas. The technologies can be rated according to the following answers:

- **New:** the paper presents a technology, but it is not based on other technologies;
- **Existent:** the paper presents a technology, but this proposal was based on other technologies.

Regarding SQ3 (*Context of Use*), its goal was to identify where the technologies are being proposed and currently used. The technologies can be rated according to the following answers:

- **Industrial:** the papers presents a technology used or evaluated in an industrial context;
- **Academic**: the papers presents a technology used or evaluated in an academic context;
- **Both:** the paper presents a technology used or evaluated in industrial and academic contexts.

Regarding SQ4 (*Phase of the Development Process*), its goal was to identify in what stage the new technologies can be used. The technologies can be classified in one or more SWEBOK (Software Engineering Body of Knowledge) high-level process (SWEBOK, 2004):

- **Requirements:** technologies employed to design/evaluate the artifacts aimed at identifying the users' needs;
- **Design:** technologies that help to design/evaluate the artifacts that are created before coding;
- **Construction:** technologies that help designers as they carry out the coding of application;
- **Verification, Validation & Testing** (V, V&T): technologies that help: (a) to verify that the product meets the user requirements (Verification), (b) to ensure consistency, completeness and correctness of the application (Validation); and (c) to examine the behavior of the application through its execution (Testing);
- **Maintenance:** technologies that verify the usability while maintaining the application.

Regarding SQ5 (*Specific life cycle*), its goal was to identify which technologies can be applied (or not) in specific development processes. We verified whether the identified technology is applied in a specific life cycle:

- **Yes:** the technology is used in a specific life cycle (Spiral, Star, among others);
- **No:** the technology is not employed in a specific life cycle.

Regarding SQ6 (*Designed/Evaluated Object*), its goal was to identify the object in which the technology was employed. For example, prototypes, web applications, among others.

Regarding SQ7 (*Empirical Evaluation*), its goal was to assist in the identification of which technologies were empirically evaluated. The technologies can be classified according to the following answers:

- **No:** if it does not provide any type of empirical evaluation of the technology presented in the paper;
- **Yes:** if the paper presented any kind of empirical evaluation of the proposed technology.

Regarding SQ8 (*Research Type)*, its goal was to identify the type of research that was adopted in the paper. A paper can be classified according to classification proposed by Wieringa et al. (2006):

- **Evaluation Research:** the paper shows how the technologies are implemented in practice and what are the benefits and drawbacks;
- **Proposal of Solution:** the paper proposes solution technologies and argues for its relevance, without a full-blown validation. The technologies must be novel, or at least a significant improvement of an existing technique;
- **Validation Research:** the paper shows

technologies that are novel and have not yet been implemented in practice;

- **Philosophical Papers:** these papers sketch a new way of looking at existing things by structuring the field in form of a taxonomy or conceptual framework;
- **Opinion Papers:** these papers contain the author's opinion about what is wrong or good about something, how we should do something, etc.;
- **Personal Experience Papers:** these papers explain on what has been done in practice.

Regarding SQ9 (*Tools support*), its goal was to identify which technologies need (or not) tool support in order to be applied. The technology can be classified according to the following answers:

- **Yes:** the technology presented in the paper requires some specific tool support;
- **No:** the technology presented in the paper does not require specific tool support.

The package containing information about this SM is available in Silva et al. (2014).

2.5 Selection of Papers

The execution of this SM presented the following preliminary result. A total of 124 papers (see Table 3) were selected. These papers were selected based on the inclusion criteria (see Table 2).

Table 3: Results of the conducting stage.

Selected Libraries	Returned Papers	Selected Papers	
		1º Filter	2º Filter
IEEExplore	59	57	36
Scopus	170	135	88
Total of Extracted Papers			124

In the selection process, few papers appeared in more than one digital library. However, these papers were counted only once and in the order of the performed search (IEEExplore and then Scopus).

3 QUANTITATIVE RESULTS

3.1 Overview of the Studies

The overall results, which are based on counting the studies that are classified in each of the answers to our research sub-questions, are presented in Table 4.

Although 124 papers were selected, in Table 4 we only counted 123. This is because one of the selected papers from our review is a Systematic Literature Review. For that type of paper, we have prepared another type of data extraction strategy.

Note that sub-questions Q4 and Q6 are not exclusive. Therefore, a paper can be classified in one or more of the possible answers. The summation of the percentages is therefore over 100%. For example, regarding Q4, some technologies may be used in more than one stage of the development process. Similarly, in sub-question Q6, a technology can be applied to design / evaluate more than one artifact.

Table 4: Results from the SM for each of the Sub-Questions.

Research sub-question	Possible answers	Results	
		Number	Percentage (%)
Q1. Type of technology	Methods	50	40.65
	Tools	25	20.33
	Frameworks / Approach	23	18.70
	Techniques	16	13.01
	Models	6	4.88
	Methodology	3	2.44
Q2. Origin of the technology	New	12	9.76
	Existing	111	90.24
Q3. Context of use	Industrial	27	21.95
	Academic	87	70.73
	Both	9	7.32
Q4. Phase of the development process	Requirements	22	13.58
	Design	27	16.67
	Construction	4	2.47
	V, V & T	109	67.28
	Maintenance	0	0.0
Q5. Specific life cycle	Yes	17	13.82
	No	106	86.18
Q6. Designed / Evaluated Object	Applications	76	50.67
	Models	24	16.00
	Interfaces, Mockups or Prototype	43	28.67
	Others objects	7	4.66
Q7. Empirical Evaluation	Yes	90	73.17
	No	33	26.83
Q8. Research Type	Evaluation Research	5	4.07
	Proposal of Solution	37	30.08
	Validation Research	77	62.60
	Philosophical Papers	0	0.00
	Opinion Papers	1	0.81
	Personal Experience Papers	3	2.44
Q9. Tools support	Yes	28	22.76
	No	95	77.24

3.2 Publication Year

The reviewed papers were published between 1988 and 2013. From a temporal point of view (Figure 1), there was an increasing number of publications between the years 2005 and 2007. One can also see, according to the papers collected from this SM, that in the years 2008 and 2011 there was a decrease in the number of published papers. The year of 2012 is the year with most published papers (15.32%), followed by 2010 (11.29%), 2009 (10.48%) and 2007 (10.48%). As this SM was conducted in January 2014, not all conferences held in 2013 had its publications in indexed searchable digital libraries. This may be the reason for the low number of papers in that year.

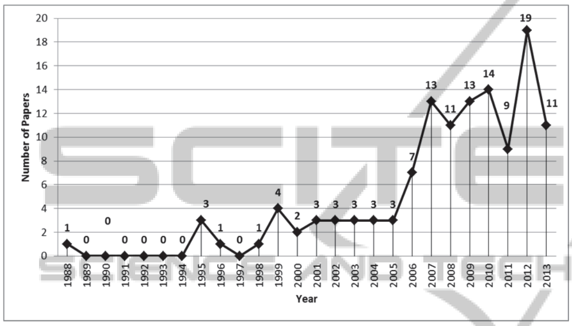

Figure 1: Temporal view of papers.

4 QUALITATIVE RESULTS

4.1 Type of Technology (SQ1)

The results for this sub-question showed that about 40.65% of the papers presented methods. For example, Fernandez et al. (2012a) proposed a usability inspection method called WUEP (Web Usability Evaluation Process). Around 20.33% of the papers present a tool. For instance, Vaz et al. (2012) presented WDT Tool that assists the identification of usability problems in web applications. Around 18.70% of the papers presented some approach/framework. For example, Liang and Deng (2009) presented a framework that describes the Computer-Supported Cooperative Work from the perspective of the Cognitive Walkthrough technique. Around 13.01% of the papers presented a technique. For example, Bonifácio et al. (2012) proposed a usability inspection technique for web mobile applications. Around 4.88% of the papers showed models. Ibrahim et al. (2007) presented a model that helps to assess usability in sonification applications. Furthermore, 2.44% of the papers presented methodologies, as presented in Sivaji et al. (2013).

4.2 Origin of the Technology (SQ2)

The results for this sub-question showed that around 90.24% of the technologies found in the papers were based on other existing technologies in the literature. For instance, Conte et al. (2007) proposed a technique that combines perspectives of Web design with the heuristics proposed by Nielsen (1994). Around 9.76% of the papers describe a technology that is not based in other technologies. For example, Pankratius (2011) presents a tool that aiming to collect subjective information from the programmer while it performs the coding of the application.

The results of this sub-question (SQ2) and the previous sub-question (SQ1) indicate that several technologies are being proposed in the literature. These technologies aim at assisting primarily both the designers of IHC as well as software engineers, improving usability in the development process of applications by designing or evaluating usability.

4.3 Context of Use (SQ3)

The results for this sub-question showed that about 70.73% of the technologies presented were used in an academic context. For example, Fernandes et al. (2012) conducted two empirical studies in an academic context with undergraduate students. Around 21.95% of the technologies were applied in an industrial context. Sivaji et al. (2013), for example, conducted two case studies in two industry software projects with experts in usability. Furthermore, 7.32% of the technologies presented were applied in both Academic and Industrial context, as presented in Vaz et al. (2012).

The results of this sub-question show that most of the technologies found in this SM are being proposed and/or evaluated in the academic context. This because is more costly for the industry to provide part of the time of the practitioners to perform evaluations. One of the solutions found by the researchers is to conduct these evaluations in the academic context, with undergraduate or graduated students. Some of these students working in the industry and already have the professional profile expected to participate of the evaluations.

4.4 Phase of the Development Process (SQ4)

The results for this sub-question revealed that 67.28% of the technologies are used during the V, V&T phase. In this phase, we have divided the selected technologies in two categories as suggest by

Fernandez et al. (2011): (1) *Usability Inspection* and (2) *Usability Testing*. Of the total number of technologies applied during the V, V&T, 44.95% are technologies for *Usability Inspection*. For example, Fernandes et al. (2012) present an usability usability inspection technique, called WE-QT (Web-Question Evaluation Technique) which helps novice inspectors to identify usability problems for Web applications. And, of all the technologies used in V, V&T phase, 55.05% are technologies are for *Usability Testing*. One example is the proposed tool by Fabo et al. (2012) that identifies usability problems through automatic data capture. Around 16.67% of the technologies can be used in the Design phase, as technique proposed by Rivero and Conte (2012). Around 13.58% of the technologies can be used in the Requirements stage. For example, Ormeño et al. (2013) presented a new method to capture usability requirements. Around 2.47% of the technologies can be used while developers perform the coding of application, as the tool proposed by Pankratius (2011). We did not find any a technology that is used in the maintenance phase.

The results of this sub-question indicate that there is a need for technologies that can be used in the initial stages of development (Requirements and Design). However, the found usability problems in the final stages are corrected with the higher the cost, also increasing the time for professional development and maintenance of the application.

4.5 Specific Life Cycle (SQ5)

The results for this sub-question revealed that 86.18% of the technologies are not used in a specific life cycle. Thus, such technologies may be suitable for the development life cycles adopted in industry. Moreover, 13.82% of the technologies are used in a specific life cycle. For example, Sivaji et al. (2013) presented a hybrid approach that integrates the Heuristic Evaluation and Usability Testing in a life cycle of specific development. The results for this sub-question indicate that 86.18% of technologies are used regardless of the life cycle adopted by the development team. However, 13.82% of the selected technologies are using a specific life cycle (e.g. the Model Driven Development - MDD, the Architecture Driven Development - ADD).

4.6 Designed / Evaluated Object (SQ6)

The results for this sub-question revealed that 50.67% of the technologies presented already developed applications as an object being designed or evaluated. From the total technologies that design/evaluate applications, 52.65% of these technologies have been used in Web applications, 26.30% in Desktop applications, 3.94% in Mobile applications and 17.12% did not specify which application the technology was evaluating. Approximately 28.67% of the technologies employed interfaces, mockups or prototypes as objects. An example is the method proposed by Ormeño et al. (2013). Around 16% of the technologies employed models as objects, as the method proposed by Rivero and Conte (2012). And 4.66% of the technologies employed other objects, such as the lines of code (2%), log files (2%) and user tasks (0.66%).

The results for this sub-question indicate that many technologies are being developed to improve the usability in applications, especially focused on the Web. However, a point to be considered is the low number of technologies that help to improve the usability in Mobile applications. With the growth in use of mobile devices, mobile applications are becoming increasingly present among users.

4.7 Empirical Evaluation (SQ7)

The results for this sub-question revealed that in 26.83% of the selected technologies didn't any type of empirical evaluation. For instance, Díscola and Silva (2003) describe an approach, but the authors did not perform an empirical study. Around 73.17% of the technologies were evaluated empirically. For instance, Santos et al. (2011) describes the evolution of an assistant through empirical studies.

The results for this sub-question show that almost 74% of the papers carried out an empirical evaluation in the technologies they are proposing. Conducting empirical studies is a common practice in the areas of Human Computer Interaction and Software Engineering. These two areas are interested in evaluating and improving the proposed technologies so that they can assist practitioners during the usability design/evaluation.

4.8 Research Type (SQ8)

The results for this sub-question revealed that 62.60% of the papers presented a Research Validation. Conte et al. (2009) presented a Research Validation. Approximately 30.08% of the papers presented a Proposed Solution. Ormeno et al. (2013) presented a proposed solution, but did not present how this proposal would be used in practice. Around 4.07% of the papers presented a Evaluation

Research. For example, Winter et al. (2011) presented a technology and also commented on the advantages and disadvantages of using the proposed technology for the industry. Approximately 2.44% of the papers present Papers of Professional Experience. For example, Nayebi et al. (2012) reported how three usability evaluation methods can be used in mobile applications. And 0.81% of the papers presented a Opinion Papers. Mueller et al. (2009) present several important points of how to conduct usability testing. We did not find any Philosophy Paper in this SM.

The results for this sub-question indicate that many papers are presented to validate the technologies that are being proposed. This may be an indication that researchers are trying to improve the proposed technologies for them to be used in the academic or industrial context. Moreover, another important result is the number of papers that present new Proposed Solutions (30.08%), describing technologies that aim to solve usability problems during the development process.

4.9 Tools Support (SQ9)

The results for this sub-question indicated that 22.76% of the technologies require a tool or framework to assist practitioners. As mentioned earlier, there are the tools proposed by Vaz et al. (2012) and Santos et al. (2011). However, about 77.24% of the technologies do not require tool support. As mentioned earlier, we have the research by Ormeno et al. (2013) and others. The tools found in the majority (22.76%) are available under a (paid) license or are unavailable for use by practitioners (academic tools). Such features translate into a higher employment of technologies that do not require tool support. Tools can increase performance by reducing overhead and facilitating the work of practitioners in the development process. Therefore, tool support technologies that are available for use can reduce the effort of practitioners during the development of interactive applications and, consequently, provide many benefits to the industry.

5 DISCUSSION

As mentioned before, in this SM we found a secondary study, a systematic review proposed by Fernandez et al. (2012). This systematic review cannot be classified according to our research sub-questions because the data collected in our sub-questions is specific to technologies rather than systematic mappings or systematic reviews. We related the technologies found in our systematic mapping with the technologies found in the systematic review by Fernandez et al. (2012). Through this relationship, one can see that the technologies found by Fernandez et al. (2012) are more specific (in context) than the technologies found in this SM. This happened because Fernandez et al. (2012) searched for technologies that evaluate usability in the context of Web applications. Our SM, on the other hand, aimed at identifying technologies in a broader context, that is, technologies that assist in the design and/or evaluation of usability in the development process. Our SM takes into account any type of application, not just Web applications. Therefore, our mapping is broader. It identified technologies evaluating the usability of web applications, mobile applications, and desktop applications, among others. Additionally, our SM not only identified technologies that assess usability, but also technologies that assist in the design process, aiming at improving usability.

6 CONCLUSIONS

This paper presented a Systematic Mapping (SM) that discussed the existing evidence on the technologies proposed for the areas of HCI and SE that can be used within the software development process. From an initial set of 229 papers, a total of 124 research papers were selected for this SM.

The results obtained in this SM identified several technologies that focus on supporting HCI designers and software engineers in improving the usability of interactive applications. The results also show that there is a need for the creation of new technologies to support the usability of the applications from the early stages of the development process. This is because correcting usability problems in the early stages is less expensive and avoids rework effort from practitioners. This SM found evidence of several research gaps for researchers from both areas, such as: the creation of new technologies for the early stages, reducing costs and the amount of usability problems found in the assessments of usability in the final stages of the development process; to assist practitioners in designing applications aiming at usability. And, to help the integration of technologies, with a focus on improving the usability within the development process of mobile applications. From the results of this SM it is possible for both software engineers and HCI designers to identify technologies that can be applied in the industrial context. As future work, we intend to expand and update this SM in order to increase the body of knowledge with new technologies and studies that can help identify new research topics.

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